SOME EDAPHIC RELATIONS OF SOUTHEASTERN IDAHO WILDLANDS[1]

Mark E. Jensen[2]

Abstract.— Soil samples from the A1 horizon and dominant subsoil horizon at 190 sites were analyzed for Ca, Mg, K, P, and organic matter contents in conjunction with a soil resource inventory of the Caribou National Forest. Vegetative composition and production data were compared to the edaphic factors to derive relationships useful to the land manager. Organic matter was effective in distinguishing between soil orders and was positively correlated to vegetative production. Vegetative cycling of the nutrients P and K was most pronounced in soils of the order Mollisols, to a lesser degree in the Alfisols, and not at all in the Entisols. The K/Mg ratio of the soil showed a negative correlation to grass production and a positive correlation with shrub production. An interpretative table is provided to aid determinations of high versus low values for the edaphic factors studied.

Soil scientists of the Intermountain Region, U.S. Forest Service, are commonly required to provide the land manager information concerning the soils management potential. Such information is usually based solely upon soil morphological features due to the lack of soil nutrient data available for wildlands of this region.

The primary objective of this study was to determine modal values for some soil nutrients within the soil groups of the Caribou National Forest, southeastern Idaho. Such information is needed if future collection of soil nutrient data on such lands is to have a basis for comparison. A secondary objective was to determine what relationships exist between nutrient levels in the soil and vegetative production and composition.

Study Area

The Caribou National Forest is located in southeastern Idaho, covering an elevational range of 1490 to 2930 m (Fig. 1). It occurs mainly within the Middle Rocky Mountain physiographic province, with some inclusion of the Basin Range physiographic province (Fenneman 1931). The geology is complex, ranging from Precambrian metamorphics in the Bannock and Portneuf ranges to Jurassic-Triassic sedimentaries in the Bear River and Webster ranges to Cretaceous sedimentaries in the Caribou Range.

Baily (1980) has classified the vegetation of the Caribou National Forest as belonging to the Rocky Mountain Forest Province, Douglas-Fir Forest section and the Intermountain Sagebrush–Wheatgrass section. The climate is a semiarid steppe regime with a wide range in mean annual precipitation. The lower elevations receive 330 mm of precipitation per year, and the higher elevations receive 1524 mm annual precipitation. Approximately 60% of the precipitation on the area is in the form of snow. Elevation and aspect exert a strong influence on growing season, with microclimatic variables playing a dominant role in determining the vegetative composition and production on sites.

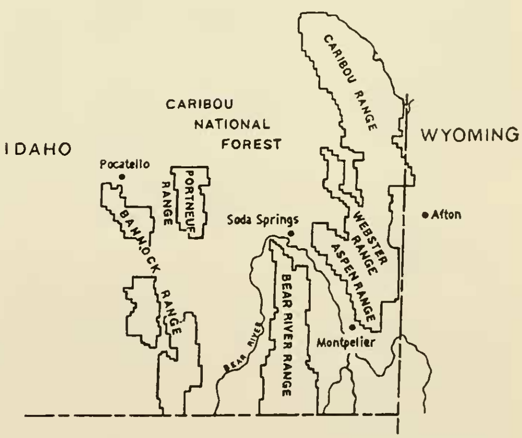

Fig. 1. The Caribou National Forest in southeastern Idaho.

[1]Contributed by the Caribou National Forest, Pocatello, Idaho.
[2]Humboldt National Forest, Elko, Nevada 89801.

METHODS

Between 1975 and 1981 a soil resource inventory was conducted on approximately 485,640 ha of the Caribou National Forest. An order 3 soil survey was used in identifying landtypes as the mapping units (Wertz 1972). This is a broad level reconnaissance survey that utilizes the factors of soil formation (Jenny 1961) to identify the soils of the mapping unit. One hundred thirty landtypes with an average size of 259 ha were mapped. The modal soils of the mapping units were identified to family level utilizing the guidelines of *Soil Taxonomy* (USDA 1975). Composition of soil subgroups analyzed for nutrient content are presented in Table 1. Sampling was designed to cover the full range of dominant soils encountered.

Samples of the Al horizon and the dominant subsoil horizon (argillic or cambic horizon for the soil orders Mollisols and Alfisols and the C horizon for the soil order Entisols) were collected, air dried in the lab, and crushed before sieving through a 2-mm screen. Soil organic matter was determined by the Walkley-Black method, and available phosphorus (P) was determined by the Dilute Acid-Flouride method (Black 1965). Soil nutrients [potassium (K), magnesium (Mg) and calcium (Ca)] were determined in liquid solutions drawn from soil-water slurries having a ratio of 1 to 2. Slurries were agitated for 12 hours on a mechanical shaker. The resultant soil paste was transferred to a Buchner filter for extraction of a sediment-free filtrate. One to two drops of sodium hexametaphosphate were added to each extract to prevent the precipitation of $CaCO_3$. Levels of K, Mg, and Ca were determined from the filtrate in parts per million by use of an atomic absorption spectrophotometer.

Vegetative information was collected by the site analysis and ocular methods used by Intermountain Region Forest Service range personnel (USDA 1969). Composition values provided by these methods are estimates of the percentage of the total production contributed by each species on a site. All statistical tests followed Zar (1974).

TABLE 1. Composition of the soil mosaic of the Caribou National Forest.

Soil subgroups	Relative extent of the Caribou N.F. (% by area)
Argic Pachic Cryoborolls	10
Cryic Pachic Paleborolls	2
Pachic Cryoborolls	5
Argic Cryoborolls	18
Typic Cryoborolls	10
Typic Argixerolls	1
Typic Haploxerolls	2
Mollic Cryoboralfs	7
Typic Cryoboralfs	3
Typic Cryorthents	5
Typic Xerorthents	1

RESULTS AND DISCUSSION

Soil Groupings

A total of 26 soil families were analyzed in this study (Table 2). A high proportion (about 78%) of the soils studied were from the Mollisol soil order. These soils tend to support most of the highly productive rangeland sites on the study area. The Alfisol soil order is commonly associated with timber sites, but occasionally support rangeland. Entisols are highly variable, with some commercial-size timber and some lower-production-potential rangeland. Entisols are often associated with hill slopes of high runoff potentials and are commonly managed for watershed values on the study area.

In making comparisons between soil families, it was necessary to group some families to higher levels of the soil classification system, due to limited sample size. *Soil Taxonomy* provides a hierarchical classification system that allows for the grouping of soils from lower to higher categories. In making such groupings, increased variability is introduced into the sample of soils; yet it is still possible to make reasonable predictions about responses to management and manipulation within the higher soil groupings.

Edaphic Factors

Edaphic factors offer criteria for making distinctions between the soil groupings (Table 3). In particular, the Mollisols, Alfisols, and Entisols possess noticeable differences in soil nutrients. The Mollisols exhibited the highest overall mean values for the nutrients studied, followed by Alfisols. Entisols showed the lowest levels. This is consistent with genesis processes involved with development of these soils (USDA 1975).

A Newman-Keul multiple range test for unequal sample size was performed on the data to examine if significant differences in mean values existed (Zar 1974). The three soil orders differed significantly in respect to organic matter in the Al horizon (Table 4).This result is as expected, in that soil organic matter is controlled by long-term vegetative production and species composition on a site. These factors in turn affect soil development. Phosphorus also showed significant differences between soil orders, but K, Mg, and Ca did not.

Table 5 presents an interpretive guide for some plant nutrient levels in the soils studied. The values reported can be used to determine whether new Al horizon nutrient values are unusual. The levels reported are based on means and standard deviations for samples taken from each soil order on the Caribou National Forest. Caution is suggested in applying these relations to soils and site conditions significantly different from those of this study.

Nutrient Cycling Relations

The degree of nutrient cycling within Mollisols, Alfisols, and Entisols was studied. The nutrients P and Mg were analyzed with respect to concentrations in the Al and the subsoil of selected profiles. If P and Mg were not being cycled by vegetation, one would expect higher levels of both elements in the subsoil horizon sampled. Table 6 shows that both P and Mg are being rapidly pumped from subsoil to Al horizons in Mollisol soils. Magnesium is significantly more concen-

TABLE 2. List of soil families considered with associated vegetation types and sample size.

Soil family	Associated vegetation types	Sample size
	Order Mollisols	
Fine, mixed, Argic Pachic Cryoborolls	Aspen, Mountain Brush, Sage-Grass	4
Fine loamy, mixed, Argic Pachic Cryoborolls	Aspen, Mountain Brush, Sage-Grass	24
Clayey skeletal, mixed, Argic Pachic Cryoborolls	Aspen, Mountain Brush, Sage-Grass	3
Loamy, skeletal, mixed, Argic Pachic Cryoborolls	Aspen, Mountain Brush, Sage-Grass	4
Fine loamy, mixed, Cryic Pachic Paleborolls	Mountain Brush, Sage-Grass, Dry Meadow	8
Fine loamy, mixed, Pachic Cryoborolls	Aspen, Mountain Brush, Sage-Grass	4
Coarse loamy, mixed, Pachic Cryoborolls	Aspen, Mountain Brush, Sage-Grass	4
Loamy skeletal, mixed, Pachic Cryoborolls	Aspen, Mountain Brush, Sage-Grass	4
Fine, mixed, Argic Cryoborolls	Sage-Grass, Forb	12
Fine loamy, mixed, Argic Cryoborolls	Mountain Brush, Sage-Grass	19
Loamy skeletal, mixed, Argic Cryoborolls	Mountain Brush, Sage-Grass	24
Fine loamy, mixed, Typic Cryoborolls	Sage-Grass	3
Loamy skeletal, mixed, Typic Cryoborolls	Mountain Brush, Sage-Grass	12
Fine loamy, mixed, mesic, Typic Argixerolls	Juniper, Mountain Brush, Sage-Grass	10
Loamy skeletal, mixed, mesic, Typic Argixerolls	Juniper, Mountain Brush, Sage-Grass	5
Loamy skeletal, mixed, mesic, Typic Haploxerolls	Juniper, Mountain Brush, Sage-Grass	8
	Order Alfisols	
Fine, mixed, Mollic Cryoboralfs	Pine, Fir, Mountain Brush	5
Fine loamy, mixed, Mollic Cryoboralfs	Pine, Fir, Mountain Brush	6
Loamy skeletal, mixed, Mollic Cryoboralfs	Pine, Fir, Mountain Brush	3
Fine loamy, mixed, Typic Cryoboralfs	Pine, Fir	6
Loamy skeletal, mixed, Typic Cryoboralfs	Pine, Fir	4
	Order Entisols	
Fine loamy,mixed, Typic Cryorthents	Pine, Fir, Sage-Grass	4
Loamy skeletal, mixed, Typic Cryorthents	Pine, Fir, Sage-Grass	4
Fine loamy, mixed, mesic, Typic Xerorthents	Juniper, Sage-Grass	4
Loamy skeletal, mixed, mesic, Typic Xerorthents	Juniper, Sage-Grass	4
Sandy skeletal, mixed, mesic, Typic Xerorthents	Juniper, Sage-Grass	3

trated in the Al than in the subsoil of Alfisols, and, although P shows a strong trend in the same direction, the difference is not statistically significant. There is only a slight hint of nutrient pumping in the Entisols considered here. A Wilcoxon paired sample test was used to determine if the nutrient contents of the horizons represented different populations (Zar 1974).

The data suggest (Table 6) that vegetation on Mollisols (aspen, mountain brush, and sage-grass types) are effective in cycling nutrients each year from the subsoil to the surface. Such data have relevance for recommendations frequently made by forest soil scientists to stockpile top soil before initiation of site-disturbing activities. Top soil is widely valued for its beneficial physical and chemical properties for site reclamation (Brady 1974). My results suggest that top soil storage would be highly desirable for Mollisols and probably for Alfisols as well, but the practice could hardly be justified for the En tisols considered here.

Soil Taxonomy Implications

Soil organic matter appears to be the best indicator of soil variability and potential of

TABLE 3. Nutrient values for Al horizons by various soil groupings.

Soil group	P(ppm)	Ca(ppm)	K(ppm)	Mg(ppm)	Organic matter (%)	Production°	Mollic Epipedon depth°°
Fine and fine loamy families of Argic Pachic Cryoborolls	n = 43	27	27	35	43	43	43
	x̄ = 48.6	17.3	11.2	14.9	5.1	1,882	53.6
	s = 14.3	11.2	11.7	9.6	1.2	446	11.3
Fine and fine loamy families of Pachic Cryoborolls	n = 12	10	11	11	11	11	11
	x̄ = 46.8	20.9	16.8	14.4	5.4	1,634	49.9
	s = 20.5	20.6	13.6	10.8	1.5	440	14.9
Fine family of Argic Cryoborolls	n = 12	8	8	12	12	12	12
	x̄ = 47.7	10.0	12.9	13.3	4.9	1,123	26.8
	s = 16.9	5.9	5.0	8.1	1.2	293	5.0
Fine loamy family of Argic Cryoborolls	n = 19	8	8	16	21	19	19
	x̄ = 46.4	16.1	13.8	18.6	4.9	1,382	29.7
	s = 16.9	9.8	7.7	13.1	1.2	276	4.9
Loamy skeletal family of Argic Cryoborolls	n = 24	18	19	20	22	24	24
	x̄ = 45.6	17.6	18.1	12.8	4.5	1,260	29.8
	s = 19.6	10.0	13.8	3.9	1.1	383	4.8
Fine and fine loamy families of Typic Cryoborolls	n = 15	8	9	12	15	15	15
	x̄ = 29.9	24	23.8	11.4	4.5	968	27.9
	s = 21.0	15.6	21.4	7.1	1.4	333	7.6
All Argic Cryoborolls	n = 55	34	35	48	55	55	54
	x̄ = 46.3	15.5	15.9	14.8	4.7	1,284	29.0
	s = 17.8	9.4	11.2	9.1	1.2	348	4.9
All Xerolls	n = 23	10	11	19	23	23	23
	x̄ = 23.4	29.4	9.2	15.0	4.1	859	29.5
	s = 18.1	32.7	7.8	12.0	1.1	255	4.8
All Alfisols	n = 22	19	21	24	23	—	—
	x̄ = 53.4	13.0	14.4	10.4	3.2	—	—
	s = 15.9	11.2	11.6	4.6	1.6	—	—
All Entisols	n = 19	13	11	17	19	—	—
	x̄ = 21.3	14.4	6.2	9.0	2.4	—	—
	s = 20.7	10.5	8.4	6.9	1.1	—	—
All Mollisols	n = 148	89	93	124	143	147	148
	x̄ = 41.8	19.0	14.6	14.5	4.8	1,449	37.6
	s = 19.7	16.2	13.0	9.7	1.3	889	14.3

n = sample size
x̄ = mean
s = standard deviation

° = kg/ha/yr dry weight
°° = cm

TABLE 4. A comparison of mean nutrient values of the Al horizon by soil order.

Soil order	P(ppm)	Ca(ppm)	K(ppm)	Mg(ppm)	Organic matter (%)
Mollisols	41.8[a]	19.0[a]	14.6[a]	14.5[a]	4.8[a]
Alfisols	53.4[b]	13.0[a]	14.4[a]	10.4[b]	3.2[b]
Entisols	21.3[c]	14.4[a]	6.2[b]	9.0[b]	2.4[c]

NOTE: Means having the same letter in superscript do not differ significantly as determined by the Newman-Keul multiple range test for unequal sample sizes interpreted at the 95% confidence level.

the edaphic factors studied. Organic matter was found to be the most useful variable in distinguishing between soil orders, as well as Mollisol subgroups.

A criterion used in defining Mollisols is organic matter content of the mollic epipedon (USDA 1975). Specifically, the organic matter content of the mollic epipedon must be 1% or more throughout its thickness. The mean values for organic matter content of the soils considered suggest that the 1% limit is low. The mean organic matter content of Al horizons for my Mollisols was 4.8%, ranging down to 2.4% for the Entisols. The mean of the Entisols was significantly greater than 1% (Student T test interpreted at the 95% confidence level, Zar 1974). This criterion from *Soil Taxonomy* should be reconsidered for forest and rangeland soils of the Intermountain Region of the United States.

Range Production Potentials

A knowledge of organic matter content in the mollic epipedon is effective in assessing potential range production. From 100 to 500 years are needed to achieve the equilibrium content of organic matter in the mollic epipedon (USDA 1975). Vegetative production of intermountain ranges shows considerable yearly variability, making it rather difficult to assign potentials based on a single year's production. Soil organic matter offers an alternative for assessing potential, since it is an indicator of production over a long period of time.

Organic matter content of Mollisols Al horizon showed a positive correlation with vegetative production (Table 7). The correlation ($r = .62$) would probably be improved if more quantitative vegetative sampling techniques than were used in this study were employed. Production showed a good relationship to both mollic epipedon depth and elevation on selected range sites. The following multiple regression equation was developed to assist in making estimates of production potentials on the Caribou National Forest. Production (kg/ha/yr) = –3053.8 + 54.0 (mollic epipedon depth, cm) + 1.57 (elevation, m); $n = 23$ ($r^2 = .82$).

Potassium-Magnesium Ratio Implications

Vegetative manipulation practices are common in forested lands of this region of the United States, with efforts being made to change the proportion of grasses, forbs, and shrubs in the pretreatment cover. A knowledge of the K-Mg ratio of the soil's Al horizon may be useful to the land manager in making better cost-effective proposals for

TABLE 5. Interpretative table for nutrient levels of the Al horizon by soil order.

Soil order	Level	P(ppm)	Ca(ppm)	K(ppm)	Mg(ppm)	Organic matter (%)
Mollisols	Low	<22	3	2	5	3.5
	Moderate	22 to 41	3 to 19	2 to 14	5 to 14	3.5 to 4.9
	High	42 to 61	20 to 35	15 to 28	15 to 24	5.0 to 6.0
	Very high	>61	35	28	24	6.0
Alfisols	Low	<38	2	3	6	1.6
	Moderate	38 to 53	2 to 13	3 to 14	6 to 10	1.6 to 3.2
	High	54 to 69	14 to 24	15 to 26	11 to 15	3.3 to 4.8
	Very high	>69	24	26	15	4.8
Entisols	Low	< 1	4	1	2	1.3
	Moderate	1 to 21	4 to 14	1 to 6	2 to 9	1.3 to 2.5
	High	21 to 42	15 to 25	7 to 12	10 to 16	2.6 to 3.5
	Very high	>42	25	12	16	3.5

TABLE 6. Horizon differences in phosphorus and magnesium contents by soil order.

Soil order		P(ppm)			Mg(ppm)	
	Al horizon	Subsoil horizon	Difference (%)	Al horizon	Subsoil horizon	Difference (%)
Mollisols	$\bar{x}$ = 39.0	21.8	79°	15.3	7.2	113°
	s = 20.0	20.2		9.2	2.1	
	n = 70					
Alfisols	$\bar{x}$ = 51.3	35.7	44	11.1	6.0	85°
	s = 17.4	24.7		5.2	1.4	
	n = 17					
Entisols	$\bar{x}$ = 23.8	20.2	18	11.4	10.9	5
	s = 23.6	19.0		11.3	9.7	
	n = 9					

°Indicates that the Al and subsoil horizon population values are significantly different ($P<0.05$) by use of the Wilcoxon paired sample test

range improvement expenditures (K. T. Harper, pers. comm.).

Table 8 shows the relationship of this ratio to the vegetative composition of the Mollisols. A significant negative correlation was found between the K-Mg ratio and grass composition of the sites. The composition of shrubs showed a significant positive correlation to the ratio, yet the coefficient of determination was low. Errors in the determination of shrub composition probably contributed to this fact. Woodward (1981) found the same general relationships as those presented in Table 8 for 30 species of Utah range plants. The root cation exchange capacity (CEC) for the species of his study averaged 33.5 meq/100g for the shrubs, 33.2 meq/100g for the forbs, and 14.7 meq/100g for the grasses. These differences affect nutrient uptake by the plants.

The strength of attraction of a cation to a negatively charged surface, i.e., plant root, is directly proportional to the charge on the surface and the cation, and inversely proportional to the distance between them (Russel 1973). It can be assumed that the higher the CEC of a root, the more the root would tend to attract Mg rather than K. Since the shrubs of this study had significantly higher root CEC values than the grasses, we would expect them to absorb Mg from the soil solution at a greater rate than the grasses. Conversely, the rate at which shrubs absorb K would be less than that for the grasses, since the shrub exchange sites are selectively attracting divalent cations, thus creating a soil solution around the root that is enriched in divalents and impoverished in respect to monovalent cations. These relations suggest that range sites with high K-Mg ratios in the soil would favor the growth of shrubs and sites with low K-Mg ratios would favor grass production (K. T. Harper, pers. comm.). This has indeed been the case for the Utah range plants studied by Woodward (1981) and the range sites of this study.

CONCLUDING REMARKS

This study of edaphic factors on selected forest and rangelands in southeastern Idaho

TABLE 7. The relationship of vegetative dry weight production to organic matter in the Mollisol soil order. Vegetative production (kg/ha/yr) = 172.9 + 259.1 (organic matter (%) in the Al horizon): r^2 = .38, n = 147

Organic matter (%) in Al horizon	Corresponding vegetative production predictions
1	431
2	691
3	950
4	1208
5	1468
6	1727
7	1986

NOTE: Regression slope is significantly different than 0 at a 95% confidence level.

TABLE 8. The relationship of the potassium magnesium ratio of the Al horizon to vegetative composition in the Mollisol soil order.

	K/Mg	Shrub (%)	Grass (%)
Mean	1.42	39.2	33.6
Standard deviation	1.05	19.6	15.4
Sample size	73	73	73

Grass (%) = $56.4\ e^{-.39\ (K/Mg)}$; r^2 = .60, n = 73
Shrub (%) = $27.8\ e^{.24\ (K/Mg)}$; r^2 = .18, n = 73

NOTE: 1. The exponential regressions provided gave better fits than did linear regressions.
2. Regression slopes are significantly different than 0 at a 95% confidence level.

provides relationships that will be of use to managers of wildlands in the Intermountain Region of the United States. More research on wildland soils of this region is needed, since large data bases are required for development of interpretive models of soil-plant relationships.

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